Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	
Expanding Flexible Use of the 12.2-12.7 GHz Band	WT Docket No. 20-443
Expanding Flexible Use in Mid-Band Spectrum Between 3.7-24 GHz	GN Docket No. 17-183

REPLY COMMENTS OF GOOGLE LLC

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Google appreciates the Commission's continued efforts to put spectrum to its most productive and efficient uses. But while the Commission's objectives in this proceeding are admirable, insurmountable barriers appear to preclude coexistence between terrestrial mobile 5G systems and FSS terminals in the 12.2-12.7 GHz (12 GHz) band at this time.

INTRODUCTION AND SUMMARY

As an FCC-approved Spectrum Access System (SAS) Administrator in the 3.5 GHz Citizens Broadband Radio Service (CBRS),[1] Google has gained valuable insights by protecting operations of earth stations of incumbent geostationary orbit (GSO) Fixed-Satellite Service (FSS) operators from interference caused by CBRS base stations. Drawing from that experience, Google is highly skeptical that protecting numerous, geographically-dispersed non-GSO (NGSO) and Direct Broadcast Satellite (DBS) earth stations from 5G base stations and unconstrained mobile deployments in the 12 GHz band—as suggested by some commenters—is a realistic plan to enable materially usable mobile service.

[1] *Wireless Telecomms. Bureau and Office of Eng'g and Tech. Approve Four Spectrum Access System Adm'rs. for Full Scale Commercial Deployment in the 3.5 GHz Band and Emphasize Licensee Compliance Obligations in the 3650-3700 MHz Band Under Part 96*, Public Notice, 35 FCC Rcd. 117 (2020).

Google nevertheless believes that the Commission should continue to investigate potential ways that may allow for terrestrial point-to-point (P2P) or point-to-multipoint (P2MP) operations in the 12 GHz band without harmful interference to FSS or DBS operations, including possible revision of the technical rules for Multi-Channel Video and Data Distribution Service (MVDDS). Such services could complement and expand broadband delivery, especially in underserved areas, with much lower risk of harmful interference as compared to mobile 5G deployments.

I. PROTECTING 12 GHZ EARTH STATIONS FROM MOBILE BROADBAND INTERFERENCE ECLIPSES THE PROTECTION CHALLENGES IN CBRS.

Since October 2019, Google has successfully operated its SAS in the 3.5 GHz CBRS band. Google's SAS, in coordination with the other 3.5 GHz band SASs, protects 3.5 GHz band incumbents from harmful interference due to CBRS base stations (referred to as Citizens Broadband Radio Service Devices, or CBSDs). Among the protected incumbents are extended C-band receive-only earth stations operating in the CBRS band, and adjacent band (>3700 MHz) earth stations used for Telemetry, Telecommand, and Control (TT&C) operations.[2] A few hundred of these earth stations are clustered at approximately two dozen sites across the United States, and they receive downlink signals from satellites in geostationary orbit.[3] Despite having approximately 150,000 CBSDs now deployed in the CBRS band, there have not been any reports of interference to protected incumbents in the band. Google thus can speak from a position of experience in successfully protecting FSS earth stations from harmful interference by in-band (and adjacent band) mobile services.

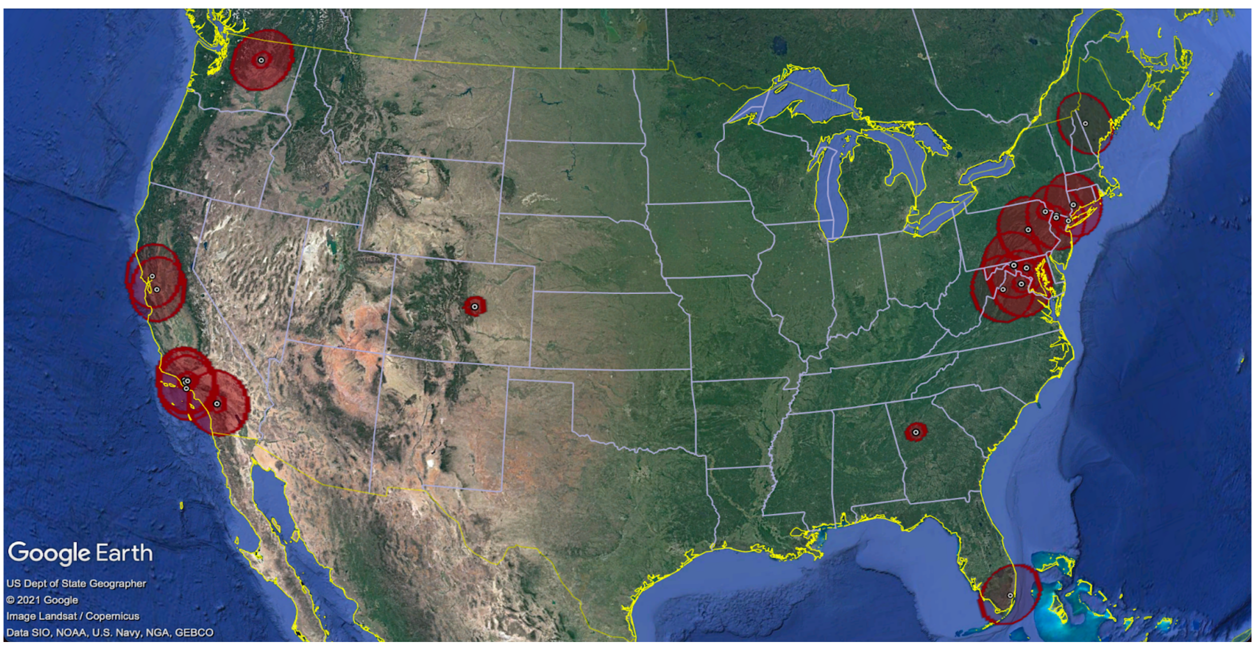
[2] *See* 47 C.F.R. §96.17.

[3] Earth station locations are publicly available through an FCC API created specifically for this purpose. *See* FCC, *3.5 GHz Band - Protected Fixed Satellite Service (FSS) Earth Stations*, https://www.fcc.gov/wireless/bureau-divisions/mobility-division/35-ghz-band-protected-fixed-satellite-service-fss-earth (last visited July 7, 2021).

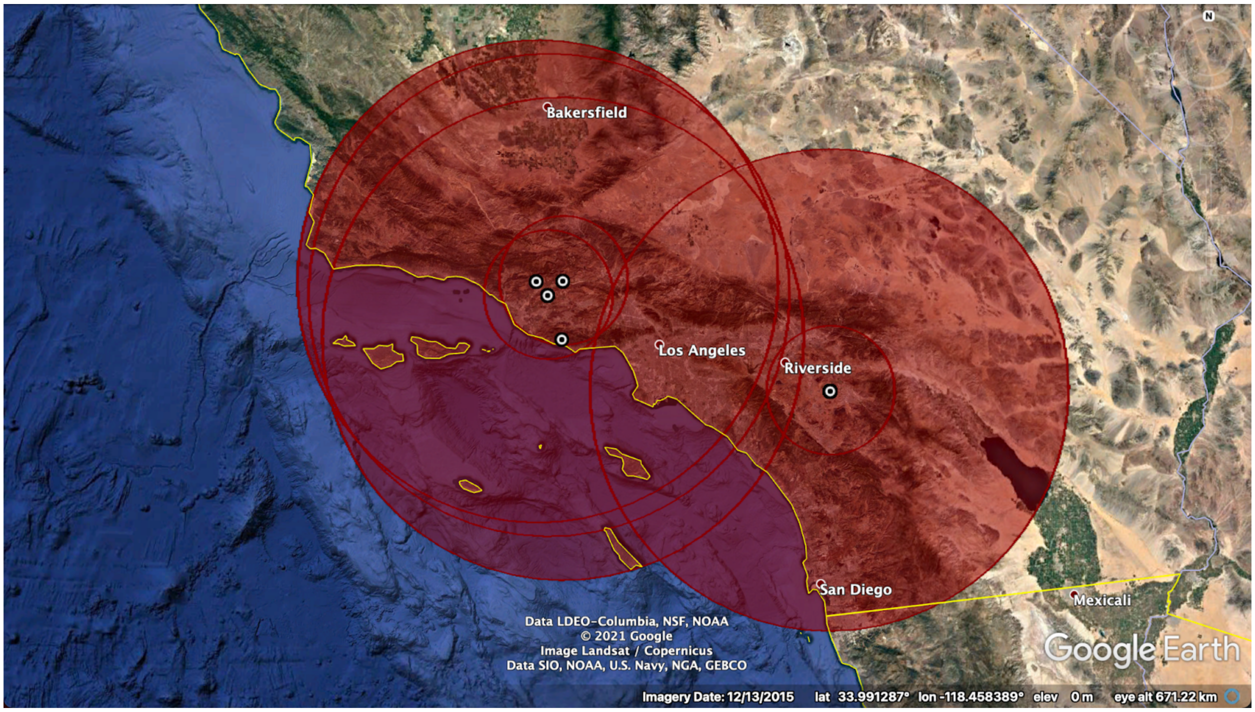
Protecting 3.5 GHz FSS earth stations can lead to significant CBRS restrictions. Guarding ubiquitous NGSO FSS terminals from interference by terrestrial mobile deployments in the 12 GHz band would be substantially more daunting, as discussed below.

A. FSS Protections Require Large Geographic Exclusion or Coordination Zones.

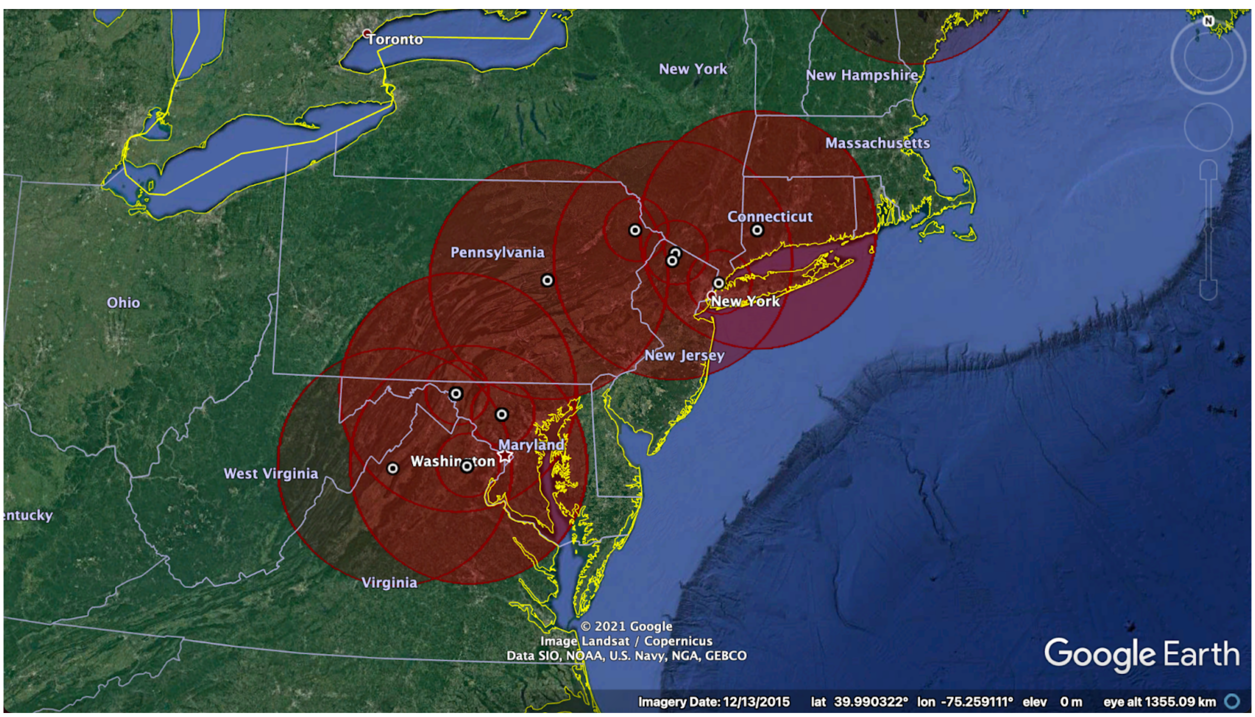
In the CBRS band, the Commission mandates exclusion or protection zones of 150 km in radius surrounding each in-band FSS earth station, resulting in a restricted area of more than 70,000 km^2 for each FSS site. The radius for adjacent band TT&C earth stations is smaller (40 km), but still creates a restricted zone of 5,000 km^2 for each site. All CBSDs in these areas must be taken into account when calculating aggregate interference to the earth stations. The maps below show the practical impact of these requirements in the CBRS band.



Map 1: Coordination zones (red circles) enforced in CBRS surrounding in-band 3.6 GHz FSS earth stations (150 km radius) and adjacent-band FSS TT&C earth stations (40 km radius) in the contiguous U.S. Only a few hundred satellite dishes are clustered in approximately two dozen sites, mostly along the coasts, compared to the potential of 1,000,000 or more 12 GHz NGSO FSS terminals.



Map 2: Closeup of the 3.6 GHz FSS coordination zones in Southern California.



Map 3: Closeup of 3.6 GHz FSS coordination zones in the Northeastern and Mid-Atlantic regions.

Assuming free space loss, where propagation loss scales with both frequency squared and distance squared, scaling the 3.5 GHz protection distances to 12 GHz band conditions results in in-band exclusion/coordination zones of greater than 40 km in radius, and larger than 5,000 km^2 in area.[4] These distances and areas give some geographic scale to considerations that must go into sharing between mobile systems such as CBRS and satellite earth stations. While the technical characteristics of C-band earth stations differ significantly from those of 12 GHz terminals (as discussed below), most of those differences work against the prospect of successful sharing in the 12 GHz band, not for it.

B. NGSO FSS Operations Are Not Compatible with Interference Management by SAS-Like Entities.

In its comments, RS Access proposes that SASs can be used to facilitate dynamic frequency coordination and control in the 12 GHz band, noting that “database and cloud technology available today can transform spectrum access from a process that took months in 2002 to one that takes a fraction of a second in 2021.”[5] RS Access is correct that SASs and similar systems allow vastly more efficient and sophisticated sharing than what was possible even a decade ago. Indeed, despite doubts voiced by some major national wireless incumbents during the CBRS rulemaking process, SASs have proved capable, reliable, and efficient in the 3.5 GHz band. But as an FCC-approved SAS Administrator since January 2020, Google has concluded that real-time management of proposed mobile sharing in the 12 GHz band is not viable at this time. The following discussion of actual SAS operations supporting CBRS, compared to what would be needed to support non-interfering mobile operations in the 12 GHz band, explains why.

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[4] $(R/150 \text{ km})^2 = (3.6 \text{ GHz}/12.45 \text{ GHz})^2$ results in R (radius) = 43 km.
[5] Comments of RS Access, LLC, in WT Docket No. 20-443, GN Docket No. 17-183, at 49 (filed May 7, 2021) (*RS Access Comments*).

1. NGSO FSS Operations Are Highly Dynamic.

First, protected C-band earth stations receive signals from satellites in GSO. Therefore, their pointing directions are nominally stationary, because the satellites being tracked do not move with respect to a point on the Earth's surface. While an earth station may receive transmissions from different satellites at different times, such changes are relatively infrequent. This is evidenced by data, including current pointing azimuth and elevation, obtained from the FCC's earth station registration API. CBRS SASs compute aggregate interference into C-band FSS earth stations once every 24 hours, which includes exchanging all local SAS data with all other SASs, taking into account any new CBSDs that are requesting new frequency assignments from any SAS, as well as any potential change in pointing direction of the FSS dish (which is infrequent).

NGSO FSS terminals like those in the 12 GHz band, on the other hand, have much more dynamic pointing. NGSO satellites are generally in low Earth orbit (LEO) and, from a given spot on Earth, are seen to transit (i.e., rise, cross the sky, and then set) in about 12 minutes or less.[6] The terminal's beam is continuously changing its pointing direction as it tracks the satellite signal. The antenna can change its pointing from one horizon to overhead to the complete opposite horizon in a few minutes, or transit a smaller portion of the sky in significantly less time, as it follows a LEO satellite across the sky. Furthermore, the terminal's antenna may change from pointing to one NGSO satellite to another even more quickly, as it switches between satellites in the constellation to optimize signal quality, satellite elevation, and load balance, among other objectives.

The highly-dynamic nature of NGSO FSS terminal operation is not compatible with the 24-hour cadence of interference management exercised by existing cloud-based spectrum

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[6] *Cf.* Heavens Above, *STARLINK-2115 - All Passes*, https://www.heavens-above.com/PassSummary.aspx?satid=47394&&showall=t (last visited July 7, 2021).

management systems such as SASs. Using such systems to manage potential interference from mobile systems in the 12 GHz band would require virtually constant recalculation of interference as NGSO FSS terminals continually repoint their antennas. For example, aggregate interference might need to be recomputed every 30 seconds or less, as compared to the every 24-hour interval required of SASs—that is, at least 2880 times more frequently. Furthermore, a SAS-equivalent system would need to be in constant communication with all NGSO FSS terminals and 5G systems, and to perform large numbers of calculations constantly, to have the information necessary to determine and implement interference protections. This level of dynamic management is not supported by current generations of spectrum sharing technology and would require substantial technical development and associated investment.

2. NGSO FSS Antennas in the 12 GHz Band Are More Susceptible to Interfering Terrestrial Signals than GSO Antennas in the CBRS Band.

In the C-band, earth stations are generally large dishes, often several meters or more in diameter. The lowest gain of any C-band dish registered for in-band CBRS protection is 42 dBi,[7] while the largest gain is 62.3 dBi.[8] Due to their design and large forward gain (and thus narrow beamwidth), these dishes have good suppression of off-axis signals. In most cases, the pointing angles of the dishes toward GSO satellites result in a maximum gain toward the horizon of -10 dBi based on the pattern envelope in the FCC's rules,[9] which is 52 to 72 dB below their main beam gain. Per Rule 25.209(a), actual performance must be at least as good as the pattern envelope requirement. These earth stations are thus exceptional at suppressing terrestrial signals from the horizon plane, which improves their rejection of potentially harmful interference.

[7] Radio Station Authorization, Call Sign KA412 (File No. SES-RWL-20190403-00461) (granted Apr. 24, 2019).
[8] Radio Station Authorization, Call Sign KA20 (File No. SES-LIC-20180112-00173) (granted Apr. 29, 2019).
[9] 47 C.F.R. §§ 25.209(a)(1), (a)(4).

In the 12 GHz band, on the other hand, NGSO FSS terminals must be smaller and more amenable to deployments at homes, small businesses, and other locations that are not major earth station facilities. Consumers will not be required to erect 20-meter dishes in their backyards. As a result, the overall performance (peak forward gain, beam size, and off-axis rejection) will not be as good as that achieved by C-band earth station antennas. Further, because the antennas are tracking LEO satellites that move across all portions of the sky, there will be times where they will necessarily point toward lower elevation angles (especially in cases where certain directions are blocked due to local obstructions, providing fewer choices of satellites). This increases their susceptibility to potential terrestrial interference coming from the direction of the horizon.

3. NGSO FSS Terminal Deployments Will Be Prolific.

NGSO FSS operators are planning extensive deployments of user terminals to serve their targeted customer bases and, in so doing, further public interest goals including extending broadband to currently unserved or underserved homes and businesses. For instance, SpaceX received an initial earth station license from the Commission authorizing it to deploy up to one million user terminals in the United States, each of which could be relocated and reconfigured on an ongoing basis.[10]

Typical mobile systems likewise involve large numbers of base stations and user terminals. In the case of 5G operations, the expectation is that a greater number of base stations will be deployed to each cover mobile devices in relatively smaller areas, so as to provide high data-rate capacity. The 12 GHz band would require even more extensive deployments for 5G as compared to sub-6 GHz bands, due to the higher frequency and

[10] Radio Station Authorization, Call Sign E190066 (File No. SES-LIC-20190211-00151) (granted Mar. 13, 2020).

propagation characteristics (i.e., greater effects of path loss due to obstructions like buildings and foliage).

Both sides of the equation—FSS sites needing protection and mobile transmitters requiring management to avoid harmful interference—are orders of magnitude greater than CBRS. For example, as of June 30, 2021, there are 156 in-band and 177 adjacent band FSS earth stations eligible for protection from CBRS, and these earth stations are concentrated in about two dozen sites. The total number of dishes to be protected (333) is about 0.03% of the potential 1,000,000 (or more) terminals that would require protection in the 12 GHz band.

4. Mobile Operations Are Unconstrained.

Regardless of whether 12 GHz mobile deployments are managed by a SAS-like system, a particular challenge with co-existence is the inability to restrict mobile device operations in the vicinity of an NGSO FSS terminal. Having multiple mobile 5G devices deployed in the vicinity of satellite user terminals in the 12 GHz band would substantially extend the separation distances needed to prevent interference to those terminals. As has been the case in other spectrum bands, this would require that the Commission impose exclusion zones or require coordination to protect incumbents. But, exclusion and/or coordination zones lack both practicality and feasibility in the 12 GHz band, as millions of both mobile devices and satellite receivers would be spread throughout the country and would be constantly added, moved, or relocated. Moreover, as noted above, exclusion zones in the 12 GHz band would be large, and would substantially limit, if not preclude entirely, meaningful new terrestrial service offerings. And, the number of exclusion zones would multiply over time as new subscribers sign up for NGSO FSS services and new user terminals are deployed, making mobile-service authorizations less and less usable in practice. The clear potential for ever-escalating levels of conflict between satellite and mobile operators, as both groups expand their services and customer bases in the same geographic areas, must be considered in assessing proposals for expanded terrestrial use of the 12 GHz band.

RS Access notes that advances in mobile technology, such as beamforming, can reduce coexistence conflicts between 5G systems and NGSO FSS terminals.[11] While 5G base stations may employ sophisticated beamforming capabilities, handsets have much less physical space and power to do so at below-millimeter wave frequencies. Beamforming antennas scale with wavelength. A 12 GHz handset antenna would need to be about 3x larger in linear dimension and about 9x the area of an equivalent antenna designed to work around 40 GHz. This raises serious questions about commercial feasibility.

Furthermore, the location of mobile devices is unconstrained. The NGSO FSS terminal could be positioned on the line of sight between the handset to its associated base station, and therefore whatever beam is formed by the handset would be pointed directly towards the NGSO FSS terminal. The base station beam would be similarly aligned. In this circumstance, beamforming would not avoid harmful interference to the FSS site.

II. CO-CHANNEL SHARING BETWEEN MOBILE AND FSS IN THE 12 GHZ BAND IS LESS FEASIBLE THAN IN THE C-BAND, WHERE THE COMMISSION FOUND IT UNWORKABLE.

After spending more than two years soliciting and analyzing comments related to the coexistence of mobile and FSS in the C-band, the Commission recently concluded that such sharing is not feasible.[12] Specifically, the FSS community is now in the midst of a $14+ billion clearing of the 3700-3980 MHz portion of the 3.7-4.2 GHz C-band to make way for terrestrial 5G under the new 3.7 GHz Service.[13] The Commission established a 20 MHz guard band between

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[11] *RS Access Comments* at iii, 40, 49.

[12] *See In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, Report and Order and Order of Proposed Modification, 35 FCC Rcd. 2343, ¶¶ 319, 321, 329-331 (2020) (declining to set aside spectrum for P2MP or flexible use in the C-band on a shared basis with FSS using coordination or dynamic spectrum management).

[13] *See id.* ¶¶ 210, 219 (estimating total C-Band clearing costs at up to $5.2 billion and authorizing a $9.7 billion accelerated relocation payment).

the 3.7 GHz Service and the remaining FSS earth stations in the 4.0-4.2 GHz range. Even then, it had to adopt strict limits on out-of-band and blocking emissions from 5G systems[14] to protect FSS earth stations that consist of high-performance dishes separated from the 5G systems by at least 20 MHz. The Commission further had to adopt 70 km co-channel coordination zones around a few FSS TT&C sites that will remain in operation below 4.0 GHz.[15]

The number of dishes to be protected in the 4.0-4.2 GHz band will be considerably fewer than the 18,000 dishes that existed before clearing, and their exact locations will be known through a publicly-available Commission database. In other words, the overall situation in the C-band is much less complex compared to 12 GHz in-band sharing, which would involve perhaps more than 1,000,000 satellite terminals, none of which are registered in a public database. The arguments that 5G/NGSO FSS sharing in 12 GHz is somehow easily manageable—despite being in-band and with enormous difference in scale, complexity, and earth station antenna performance—do not comport with the Commission's conclusions in the C-band proceeding.

III. TERRESTRIAL MOBILE SYSTEMS POSE AN UNTENABLE INTERFERENCE RISK TO NGSO FSS OPERATIONS.

A simple calculation shows that interference from terrestrial mobile systems represents a potential threat to NGSO FSS operations. The scenario modeled here is interference from a single 5G mobile handset that is operated at an unconstrained location in the vicinity of an NGSO FSS terminal. The following assumptions are made:

- Mobile handset transmit power (EIRP): 23 dBm
- Mobile handset bandwidth: 40 MHz
- Mobile handset power spectral density: 23 dBm - $10\log_{10}$(40 MHz) = 7 dBm/MHz
- Mobile activity factor: 20% (-7 dB)

[14] 47 C.F.R. § 27.1423.
[15] *Id*. § 27.1423(c).

- Mobile handset height: 1.5 m
- NGSO FSS terminal antenna gain toward handset: -5 dBi
- NGS FSS terminal antenna height: 1.5 m

The interference power spectral density received by the NGSO FSS terminal from the co-channel handset is:

$$I\ (\text{dBm/MHz}) = 7\ \text{dBm/MHz} - 7\ \text{dB} - 5\ \text{dBi} - PL = -5\ \text{dBm/MHz} - PL$$

where PL is the path loss between the handset and the NGSO FSS terminal. The figure below shows the computed interference power spectral density at the output of the NGSO FSS terminal receive antenna using three propagation models: free space loss, the WINNER II rural pathloss model[16] assuming line-of-sight conditions, and the WINNER II rural model assuming non-line-of-sight conditions. Also indicated on the plot by the dashed line, for reference purposes, is the interference criterion of -129 dBm/MHz used for C-band earth station protection in the CBRS rules. As in the SAS context, harmful interference may occur when the received interference power spectral density exceeds the interference criterion for any 5 MHz segment of the receiver bandpass. It is assumed that at least 5 MHz of the handset's 40 MHz-wide signal is within the bandpass of the satellite receiver.

To the extent that a roughly similar interference criterion is needed to protect 12 GHz NGSO FSS terminals from interference, the quick analysis shows that a single 5G handset, running just 200 milliwatts of power,[17] could exceed a reasonable interference criterion out to distances of about 200 m under non-line-of-sight conditions and about 1 km under line-of-sight WINNER II conditions. Based on free space loss (essentially the worst-case scenario), the interference distance approaches 3 km.

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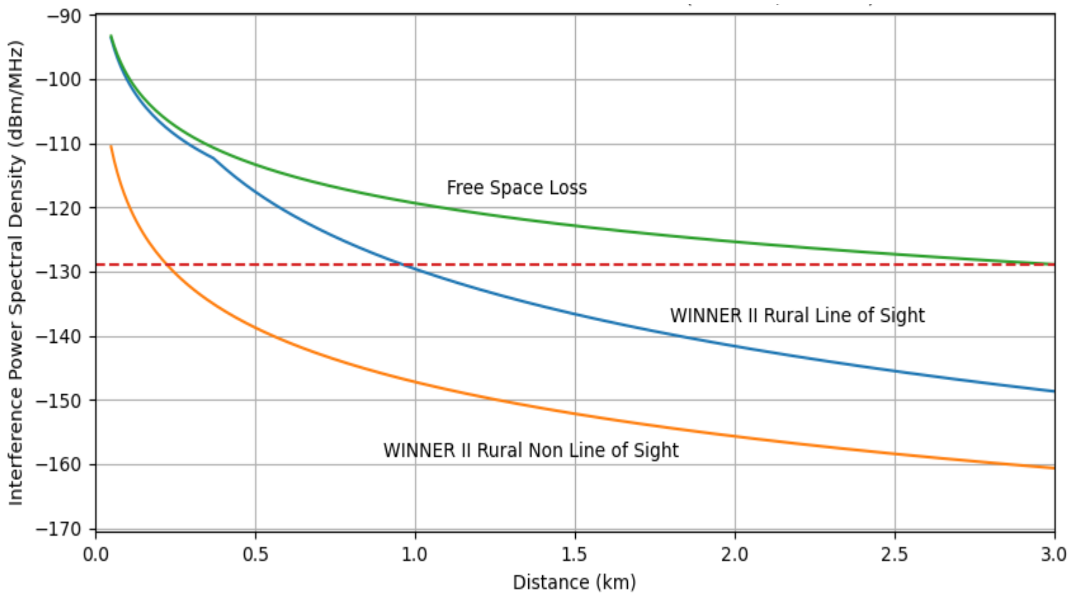
[16] P. Kyösti, *et al.*, *IST-4-027756 WINNER II D1.1.2 V1.2 WINNER II Channel Models*, Feb. 4, 2008 at Table 4.4, Model D1, https://www.cept.org/files/8339/winner2%20-%20final%20report.pdf.
[17] 200 mW (23 dBm) is the handset power allowed in CBRS (47 C.F.R. § 96.41(b)), and 1/5th as much as the allowed handset power in the 3.7 GHz Service band recently auctioned for 5G use (*Id.* § 27.50(j)(3)).



Predicted Interference from 5G Mobile (23 dBm Transmit EIRP, 40 MHz Bandwidth)

If either the mobile handset or the NGSO FSS terminal antenna is located higher than the assumed 1.5 m elevation above ground level, then the predicted interference distances under the WINNER II model become larger and mobile service becomes even more constrained.

The conclusion from this simple calculation is that a single 5G handset may be problematic for an NGSO FSS terminal at distances beyond the typical distance at which the affected FSS subscriber is likely to herself have control over the operation of the mobile device. For example, the distance is larger than the size of a typical land parcel under control of a homeowner or small business owner. Further, this simplified analysis does not take into account aggregate interference from multiple 5G handsets, which would extend the potential interference distances beyond those shown in the above table.

RKF Engineering Solutions (RKF) has simulated coexistence between 5G deployments and NGSO FSS terminals.[18] RKF's study employs Monte Carlo techniques and assumptions

[18] *RS Access Comments* at Appendix A (appending RKF Engineering Solutions, LLC, *Assessment of Feasibility of Coexistence Between NGSO FSS Earth Stations and 5G Operations in the 12.2 – 12.7 GHz Band*, May 2021.

about 5G and FSS system characteristics to determine that aggregate interference is statistically unlikely to occur, although the report does not separately present the potential interfering impact of a single UE (handset) if located in the vicinity of a satellite terminal. In other words, although RKF concludes that it is unlikely a handset will be near a satellite terminal, our calculations show that when such a situation inevitably occurs, interference can be expected out to a distance of as much as 0.2 - 1 km under realistic propagation assumptions, and as far as 3 km under worst-case conditions.

In addition, RKF's statistical results rely on several questionable assumptions and inputs that improve the simulated likelihood of successful coexistence. For example, the modeled 5G handsets are limited to an EIRP of only 20 dBm, or 100 mW, and half of the outdoor handsets operate at power levels less than about -8 dBm EIRP. It is assumed that body losses generate an additional 4 dB of attenuation. The FSS interference criterion is taken to be -120.9 dBm/MHz based on their assumed values of system temperature (200 K) and I/N objective (-8.5 dB). And, as noted by RKF, the study is generally biased toward placing satellite terminals in rural areas while placing 5G systems in more populated areas, which results in statistically fewer 5G mobile devices in proximity to NGSO FSS terminals.[19] It is not clear that these assumptions would actually apply in reality.

IV. FURTHER STUDY OF TERRESTRIAL POINT-TO-POINT OR POINT-TO-MULTIPOINT OPERATIONS IN THE 12 GHZ BAND MAY BE WARRANTED.

Google supports continued efforts to maximize the public benefits to be reaped from otherwise underutilized spectrum through innovative approaches like opportunistic spectrum sharing or "use-it-or-share-it" regimes. While shared mobile use of the 12 GHz band is likely untenable for the reasons provided above, flexible P2P or P2MP use rights in the 12 GHz band have greater potential to increase opportunities for next-generation wireless technologies and

[19] *Id.* at 5.

services. Further evaluation is necessary to determine whether a solution for opportunistic use of 12 GHz frequencies is possible that could offer adequate levels of interference protection to incumbent operations in the band. Because the existing MVDDS licenses at issue are already fixed and terrestrial, finding a viable way to change those authorizations to support competitive two-way broadband, whether through opportunistic sharing or other means, could yield a more promising outcome than the proposed mobile allocation currently under debate.

CONCLUSION

Google commends the Commission's ongoing commitment to modernizing its rules to increase the usefulness of commercial spectrum. Unfortunately, however, the 12 GHz band appears to be a poor candidate for supporting terrestrial mobile broadband at this time, due to coexistence challenges between terrestrial 5G mobile systems and FSS terminals. This reality is consistent with the Commission's carefully-considered conclusion with regard to shared 5G mobile/FSS use of C-band spectrum. Google's experience as a SAS Administrator indicates that current proposals to repurpose MVDDS licenses are unlikely to yield feasible coexistence outcomes. Instead, our experience and analysis suggests that terrestrial mobile operations in the 12 GHz band would pose significant risks of harmful interference to FSS incumbents, risks for which there currently are no apparent available solutions. Nevertheless, the Commission should continue to investigate ways to expand P2P and P2MP broadband access in the 12 GHz band spectrum on a legitimately non-interfering basis, which may become viable as spectrum sharing mechanisms continue to evolve.

Respectfully submitted,

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